EPA Research Focus

Health Effects of Near-Roadway Air Pollution

by Nalini Padmanabhan and Barbara Glenn

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In recent years, near-road exposure to air pollution has emerged as an issue in environmental health. People live, work, commute, and go to school in these environments—an estimated 45 million Americans live within 300 feet of a highway.[1] Policy-makers have attempted to reduce exposure levels; for example, California passed a law in 2004 prohibiting the construction of new schools within 500 feet of a major highway.[2] Research conducted and supported by the U.S. Environmental Protection Agency (EPA) has improved understanding of the pathway from traffic sources to health outcomes. In turn, these findings will help policy-makers understand when and where interventions are needed to reduce emissions and exposure and minimize health effects.

Near-Road Air Pollution and Health

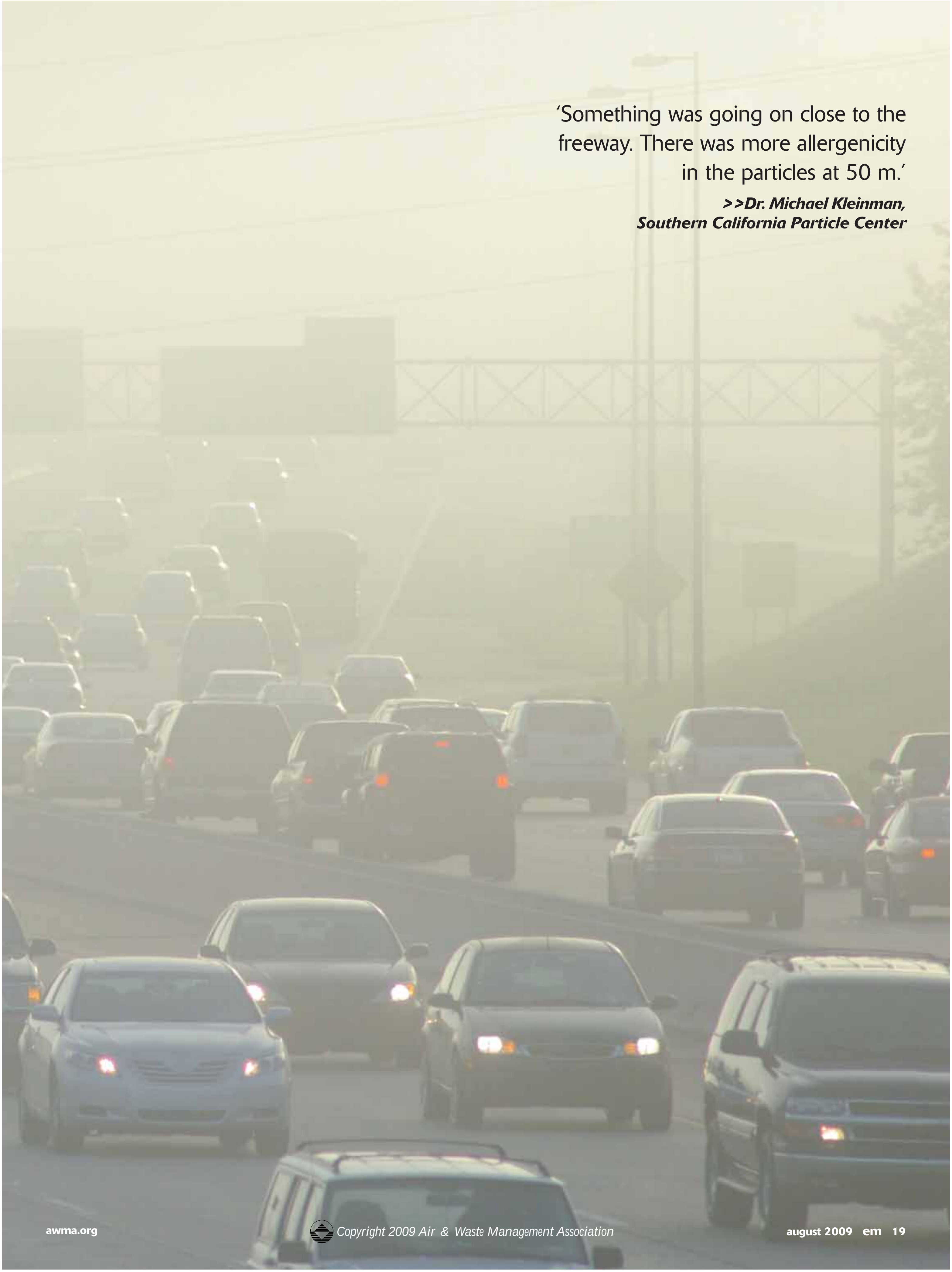
Near-road air pollution involves a complex mix of gases, vapors, and particulates that differs from other air pollution in many ways, including composition and particle size. The composition of this mix is affected by factors such as the temporal variation of traffic and sunlight patterns, and the vehicle mix of cars, light-duty trucks, and heavy-duty trucks. Influential, but often overlooked, are other products of vehicle travel, resulting from wear and tear of the road, tires, engines, and brakes.

Research has linked near-road air pollution exposure to a variety of adverse health outcomes affecting both children and adults. Most strongly established are the ties to asthma exacerbation, but recent research suggests that near-road exposure may even initiate asthma. Studies in the past few years have detected additional birth and childhood outcomes, such as retardation in lung development, cognitive effects, and increased risk of childhood leukemia. Both short-term and long-term traffic exposure may increase the risk of myocardial infarction, and reduce the rate of survival after heart failure.

Many of these outcomes are similar to those resulting from exposure to particulate matter (PM) in general, but there are important differences between the particles themselves. Near-road air has higher concentrations of ultrafine particles, resulting from fresh combustion emissions, and coarse particles, resulting from tire/brake wear and resuspended road dust. There are also significant differences in particle composition; for example, concentrations of organic compounds and metals such as aluminum, iron, manganese, lead, and zinc are significantly higher in certain size fractions of near-road particles than in other particles.

How these differences affect exposure levels and health effects is still uncertain. Research studies have used various methods to estimate people's exposure to near-road emissions, such as distance from roadway, vehicles per unit time, activity diaries, and emission data, but there has been little evaluation of these tools and consensus on their use. Several potential health effects have been proposed and substantiated to various degrees, but questions remain on the medical and social characteristics that increase susceptibility and why, how the effects take place, how they can be prevented, and the role of other influencing factors.

In 2006, EPA's Office of Air and Radiation responded to these observed effects and new science questions by identifying near-roadway research as one



'Something was going on close to the freeway. There was more allergenicity in the particles at 50 m.'

>>Dr. Michael Kleinman, Southern California Particle Center

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of its highest priority needs. The resulting Near-Roadway Action Plan integrated the many independent efforts that were being planned or already taking place.[3,4] With the goal of improving programs and activities at the federal, state, and local levels, the plan addresses several points along the pathway from source to health outcome: characterization and apportionment of sources and emissions, air quality, exposure assessments and modeling in a variety of micro-environments, and health effects.

Increasing knowledge of these health effects will prove valuable as well; according to a recent report from the Health Effects Institute on traffic-related air pollution, there is sufficient evidence to find a causal relationship between PM exposure and asthma exacerbation, but more work is still required to characterize its other health effects.[5] Research on these topics is proceeding, and the following pages highlight two ongoing studies and their results. These studies focus on the latter half of the pathway from source to health outcome, addressing the variety of health effects resulting from exposure to near-road air pollution.

Immune Responses to Near-Road Pollutant Exposure

Dr. Michael Kleinman and colleagues at the EPA-funded Southern California Particle Center studied the potential of roadway particles to aggravate allergic and immune responses in mice.[6] Using mice that were not inherently susceptible, but had been pre-sensitized by exposure to ovalbumin (egg whites), followed shortly by exposure to concentrated ambient particles, the research group tested the effect of particles at different distances from the roadway.

They found that within 50 m of the roadway, there was a significant allergic response and elevated production of specific antibodies. At 150 m and 500 m downwind of the roadway, these effects were not statistically significant. According to Kleinman, "Something was going on close to the freeway. There was more allergenicity in the particles at 50 m."

To try to explain these differences, the research group compared the composition of near-road particles to that of other ambient particles. They found that near-road particles had significantly higher mass concentrations of elemental carbon (EC) and organic carbon (OC) than other particles, but these concentrations did not differ between particles at 50 m from the roadway and those at 150 m.

However, searching the literature revealed other work showing a possible shift in the size distribution of particles during the few seconds it takes for them to travel that distance. Although the mass concentrations of EC and OC remained the same, the compounds shifted from smaller to larger particles as they reached 150 m, which deposit less efficiently in the lower respiratory tract. As a result, the effect on health is reduced.

What's Next?

Future studies will examine the ultrafine fraction of near-road particles, which with its high deposition efficiency and air toxics concentrations has the greatest capacity to generate reactive oxygen species and cause oxidative stress. Factors affecting ambient particle concentrations, such as roadway configuration and wind direction, should also be addressed. According to Kleinman, "[Future research] has to take into account meteorology…and work on mitigation in areas of maximum exposure."

"There's certainly an environmental justice issue here," he adds. "When I look around and see us building more schools near freeways, I just think we have to do better as a society."

The MESA Air Study

In 2004, EPA awarded a US$30 million grant to the University of Washington to conduct a 10-year prospective air pollution study built on the framework of the Multi-Ethnic Study of Atherosclerosis (MESA), a 10-year epidemiological study initiated in 1999 by the National Heart, Lung, and Blood Institute.

The MESA Air Pollution Study fills a gap identified in a 2001 National Research Council report by examining the impact of long-term air pollution exposure on the onset and progression of heart disease, differences in susceptibility, and the roles of PM and gaseous pollutants, including near-road pollutants. The MESA study involves more than

7000 participants aged 45–84, living in nine locations in six states.

The study's central hypothesis is that long-term fine particulate ($PM_{2.5}$) exposure is associated with a faster progression of coronary atherosclerosis and an increased risk of coronary events, such as heart attack and heart failure. Researchers are developing a state-of-the-art exposure model to examine PM variability between and within study sites using national PM monitoring system data; measurements, and variability estimates at the neighborhood, home, and individual levels; meteorological data; neighborhood and housing characteristics; individual time-activity data; and traffic data. Health effects are assessed by tracking individual clinical cardiovascular outcomes in the entire cohort and conducting pre-symptomatic atherosclerosis examinations for a subgroup of 3600 participants.

Although work on the detailed exposure model continues, researchers are beginning to publish early analyses based on MESA clinical examinations already conducted and less sophisticated measures of PM and traffic exposure.[7] According to principal investigator Joel Kaufman, "These early studies use novel health outcomes compared to previous air pollution studies, and are a step on the way to what will be a more sophisticated approach."

Traffic Exposure and Indicators of Heart Failure

Previous research has suggested a relationship between air pollution and health outcomes in individuals with heart failure disease—hospitalization, heart attack, and mortality, for example—but little is known about the impact of pollution on heart failure disease itself. A study by University of Washington researcher Victor Van Hee and colleagues, published in May's issue of The American Journal of Respiratory and Critical Care Medicine, aimed to fill this gap. It examined the effect of residential traffic exposure on two preclinical indicators of heart failure: left ventricular mass index (LVMI), measured by cardiac magnetic resonance imaging (MRI), and ejection fraction.[8]

The study involved 3827 participants, classified by the distance between their residence and the nearest interstate highway, state or local highway, or major arterial road. Four distance groups were defined: less than 50 m, 50–100 m, 101–150 m, and greater than 150 m. Overall, most participants lived within 150 m of a major roadway, but this proportion varied by location.

After adjusting for demographic, behavioral, and clinical covariates, the group found that living within 50 m of a major roadway was associated with a 1.4 g/m^2 higher LVMI than living more than 150 m from one, equivalent to the response associated with a 6-mmHg rise in systolic blood pressure. No relationship was found for ejection fraction. The association between traffic exposure and LVMI was stronger for men than for women, and in New York City, St. Paul, and Baltimore compared to Chicago, Winston-Salem, and Los Angeles. No interactions were detected for hypertension status or use of blood pressure medication.

This suggests an association between traffic-related air pollution and increased prevalence of a preclinical predictor of heart failure among people living near busy roads. According to the authors, "given that a relatively large number of individuals in this cohort live near major roadways, the public health implications of an association of this magnitude may be substantial." MESA investigators will be able to evaluate traffic-related impacts of PM on LVMI changes and ejection fraction among a subset of participants after its final examination in 2010–2012 using more precise exposure assignments accounting for within- and between-city variability.

PM Exposure, Traffic, and Systemic Atherosclerosis

Toxicology research has linked PM exposure to incidence of atherosclerosis, but epidemiological research on this link in humans is limited. To address this question, Ryan Allen and colleagues at the University of Washington studied associations between traffic proximity, background $PM_{2.5}$ levels, and abdominal aortic calcification, an indicator of systemic atherosclerosis. Their findings were published in March in *Epidemiology*.[9]

Allen's study involved 1147 participants split into two exposure groups by geocoded residence. Participants were considered highly exposed to traffic if they lived within 100 m of a highway or 50 m of a major arterial road. Again, the average residential distance from a roadway varied by city. Background concentrations were based on two-year averages between 2000 and 2002 using national $PM_{2.5}$ monitoring data interpolated to residence.

After adjusting for covariates, no overall associations were found between abdominal aortic calcification and background $PM_{2.5}$ levels or traffic proximity. However, sensitivity analyses using those participants hypothesized to have more accurate exposure estimates because of residential stability and closeness to PM monitors, found that $PM_{2.5}$ concentration was associated with an elevated risk of detectable aortic calcification and an increase in calcium score. Interpretation of results was complicated by the use of different computerized tomography (CT) scanner technologies at each location, but analyses controlled for this.

Future reports will describe results of the MESA Air study's primary focus using more direct measures of subclinical atherosclerosis in the heart, physiologic changes over time, and the impact of between- and within-city variation in PM. Developing more precise exposure estimates will help explain the effect of exposure misclassification on the ability to assess the cardiovascular risk posed by traffic pollution.

Conclusion

These examples show just two of the many ways in which near-road air pollution is emerging as an important health issue, one with outcomes as varied as allergy exacerbation, immune responses, and cardiovascular effects. Given the centrality of transportation in people's lives and the growing number of people living near roadways, it is a problem with a large potential impact on public health. **em**

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References

1. *American Housing Survey for the United States, 2007*; U.S. Census Bureau: Washington, DC, 2008; available online at www.census.gov/prod/2008pubs/h150-07.pdf.
2. Senate Bill No. 352, Chapter 668; Official California Legislative Information, 2003-2004 Session; available online at www.leginfo.ca.gov/pub/03-04/bill/sen/sb_0351-0400/sb_352_bill_20031003_chaptered.pdf.
3. Baldauf, R.; Vette, A.; Neas, L.; Costa, D. *ORD Near-Road Research Program: Draft*; U.S. Environmental Protection Agency, Office of Research and Development: Washington, DC, 2008.
4. Costa, D. EPA's Near Road Research Program. Presented to Air Quality Research Subcommittee, February 19, 2009. See www.epa.gov/osp/bosc/pdf/airoverview.pdf.
5. *Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects*; HEI Special Report 17; HEI Panel on the Health Effects of Traffic-Related Air Pollution; Health Effects Institute: Boston, MA, 2009. In press.
6. Kleinman, M.T.; Sioutas, C.; Froines, J.R.; Fanning, E.; Hamade, A.; Mendez, L.; Meacher, D.; Oldham, M. Inhalation of Concentrated Ambient Particulate Matter Near a Heavily Trafficked Road Stimulates Antigen-Induced Airway Responses in Mice; *Inhal. Toxicol.* **2007**, *19* (Supp. 1), 117-126; available online at http://dx.doi.org/10.1080/08958370701495345.
7. Gilmour, M.I. Assessment of Cardiopulmonary Toxicity in Size-Fractionated Ambient Air Samples. Presented to EPA PM Center Call-In Seminar, November 7, 2007.
8. Van Hee, V.C.; Adar, S.D.; Szpiro, A.A.; Barr, R.G.; Bluemke, D.A.; Diez Roux, A.V.; Gill, E.A.; Sheppard, L.; Kaufman, J.D. Exposure to Traffic and Left Ventricular Mass and Function; *Am. J. Respir. Crit. Care Med.* **2009**, *179* (9), 827-834.
9. Allen, R.W.; Criqui, M.H.; Diez Roux, A.V.; Allison, M.; Shea, S.; Detrano, R.; Sheppard, L.; Wong, N.D.; Stukovsky, K.H.; Kaufman, J.D. Fine Particulate Matter Air Pollution, Proximity to Traffic, and Aortic Atherosclerosis; *Epidemiol.* **2009**, *20* (2), 254-264.